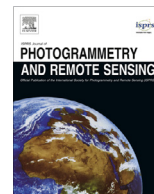




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A local descriptor based registration method for multispectral remote sensing images with non-linear intensity differences

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ABSTRACT

Image registration is a crucial step for remote sensing image processing. Automatic registration of multispectral remote sensing images could be challenging due to the significant non-linear intensity differences caused by radiometric variations among such images. To address this problem, this paper proposes a local descriptor based registration method for multispectral remote sensing images. The proposed method includes a two-stage process: pre-registration and fine registration. The pre-registration is achieved using the Scale Restriction Scale Invariant Feature Transform (SR-SIFT) to eliminate the obvious translation, rotation, and scale differences between the reference and the sensed image. In the fine registration stage, the evenly distributed interest points are first extracted in the pre-registered image using the Harris corner detector. Then, we integrate the local self-similarity (LSS) descriptor as a new similarity metric to detect the tie points between the reference and the pre-registered image, followed by a global consistency check to remove matching blunders. Finally, image registration is achieved using a piecewise linear transform. The proposed method has been evaluated with three pairs of multispectral remote sensing images from TM, ETM+, ASTER, Worldview, and Quickbird sensors. The experimental results demonstrate that the proposed method can achieve reliable registration outcome, and the LSS-based similarity metric is robust to non-linear intensity differences among multispectral remote sensing images.

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1. Introduction

With the rapid development of remote sensing technology, remote sensing images from different sensors usually differ in spectral and spatial resolutions. Remote sensing images from different sensors or different spectral bands can provide complementary information about Earth's surface. Registration of these images in a common geographic coordinate is necessary for Earth observation. As a fundamental task in image processing, image registration aligns two or more images with overlapping scenes taken at different times, from different viewpoints, or by different sensors (Zitova and Flusser, 2003). For remote sensing image processing, image registration is also a prerequisite step for image mosaic, object identification, image fusion, and change detection. An automatic solution to this problem is highly desired as conventional image

registration techniques often require manual collection of tie points¹ between the images, which is often tedious and time consuming. Different spectral bands often reflect different radiometric characteristics of the same scene resulting in significant intensity differences among the images acquired from different spectra, especially between visible and infrared imagery (Kern and Pattichis, 2007). The significant intensity differences can be visualized in Fig. 1, showing a pair of images acquired by TM band 1 (visible) and TM band 5 (infrared) sensors at the same time. Due to very different minute details now available between the multispectral images, the detection of tie points became much more difficult than ever before. Therefore, automatic registration of multispectral remote sensing images could be challenging.

Generally, automatic image registration consists of two main steps.

- (1) Image matching: detect the tie points between the reference and sensed image.

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¹ The correspondence points between the reference and sensed image.

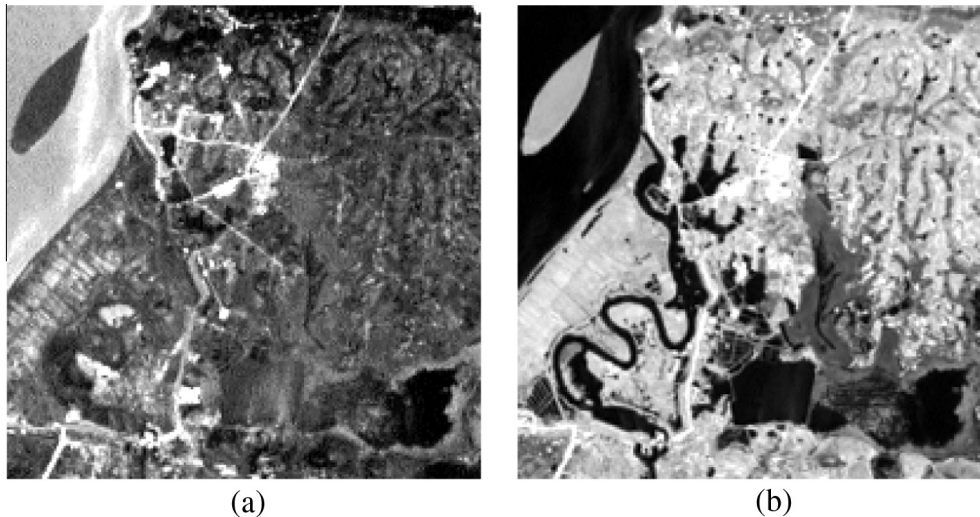


Fig. 1. The significant intensity differences between the multispectral images covering the same scene. (a) the TM band 1 image, (b) the TM band 5 image. The two images were taken at the same time.

- (2) Image rectification: Determine a transform model using the matched tie points and rectify the sensed image.

Image matching is a prerequisite for image registration and the quality of tie points influences the registration accuracy. According to the different ways of image matching, image registration methods can be classified into two categories, namely, feature-based and area-based methods (Zitova and Flusser, 2003).

Feature-based methods first extract the features (e.g., points, lines, contours) from the images and then detect the tie points based on the similarity of these features. Representative feature-based methods include contour-based method (Li et al., 1995), invariant moment-based method (Dai and Khorram, 1999), linear or edge feature-based method (Dare and Dowman, 2001), and phase congruency-based feature extraction method (Wong and Clausi, 2007, 2010). Recently, local feature descriptors have been rapidly developed in the computer vision field. The most representative local feature descriptor is the Scale Invariant Feature Transform (SIFT, Lowe, 2004), which has been widely used in the registration of remote sensing images because of its invariant to image scale and rotation changes (Li et al., 2006; Yu et al., 2008). Moreover, in order to further improve the matching performance of SIFT, some researchers have proposed a series of enhanced SIFT algorithms such as Colored SIFT (Abdel-Hakim and Farag, 2006), Scale Restriction SIFT (SR-SIFT, Yi et al., 2008), Affine-SIFT (Morel and Yu, 2009), and Uniform Robust SIFT (Sedaghat et al., 2011). However, being fundamentally similar to SIFT, these algorithms are designed for images with linear intensity changes; matching images with non-linear intensity differences is still difficult (Kelman et al., 2007; Tsai et al., 2010). Achieving enough tie points for precise registration using SIFT-based methods alone is difficult due to intensity differences among multispectral or multisensor remote sensing images. Despite being sensitive to the non-linear intensity differences, SIFT-based methods are still useful for initial registration of multispectral or multisensor images, during which two images are coarsely aligned only using a small number of tie points (Yu et al., 2008).

Different from feature-based methods, area-based methods, sometimes called template matching, first define a template window in the sensed image, and then search for a correspondence window in the reference image using different kinds of similarity metrics. The centers of matched windows are regarded as tie

points. The similarity metrics play a crucial role in the area-based methods. The conventional similarity metrics mainly include the sum of square difference (SSD), the normalized cross correlation (NCC), the mutual information (MI) and et al. SSD performs similarity evaluation through comparing the differences of grey values among images directly. As such, it is usually vulnerable to complex intensity variations. As a classical similarity metric, NCC has been widely applied for image registration because of its invariant to linear intensity changes, however, it cannot properly handle images with non-linear intensity differences (Fan et al., 2010; Hel-Or et al., 2011). MI is robust to non-linear intensity differences and has been successfully applied in the registration of multispectral or multisensor images (Cole-Rhodes et al., 2003; Kern and Pattichis, 2007). However, the registration methods based on MI is computationally expensive (Hel-Or et al., 2011), which may pose a restriction in practice. In addition, area-based methods often suffer from image distortions due to the rectangular window used in the matching process. This type of window may not cover the same part of the scene between the images with complex geometric distortions. In order to solve this problem, a pre-registration procedure could be required to reduce these distortions.

Overall, feature-based methods are more robust to the geometric distortions of images compared with area-based methods, whereas area-based methods have better resistance to the non-linear intensity differences among images. Therefore, this paper proposes an automatic registration method for multispectral images by integrating feature-based and area-based methods. The proposed method involves a coarse-to-fine registration scheme. The pre-registration is first achieved using the SR-SIFT algorithm, which improves the correct match rate for multispectral images compared with the original SIFT algorithm (Yi et al., 2008). Then, we introduce a new similarity metric based on the local self-similarity (LSS) descriptor to determine the correspondences in the fine registration stage. LSS is a local feature descriptor that captures the internal geometric layouts of images (Shechtman and Irani, 2007). Recently, the LSS descriptor has been successfully applied for the registration of thermal and visible videos, and proved to be able to handle complex intensity variations (Torabi and Bilodeau, 2012).

Upon a successful image matching, the subsequent image rectification is straightforward. Since the main objective of this paper is to develop a robust technique of tie-point detection to address the non-linear intensity differences among multispectral remote

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